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PROCESS FOR 6-O-ALKYLATION OF ERYTHROMYCIN DERIVATIVES

FIELD OF THE INVENTION

The present invention relates to a process for the preparation of 6-O-alkyl derivatives of erythromycins A and B which have use as intermediates for the synthesis of antibacterial agents. Of particular interest is use of the invention to prepare 6-O-methylerythromycin A (i.e., clarithromycin) in higher yields.

BACKGROUND

The 6-O-methylation of various erythromycin derivatives has been reported in several patents or published applications. U.S. Pat. No. 4,496,717 (issued Jan. 25, 1985) describes the methylation of a 2'-O-,3'-N-dibenzoyloxycarbonyl derivative of erythromycin by reaction with a methylating reagent in the presence of a base such as an alkali metal hydride or an alkali metal amide. U.S. Pat. No. 4,670,549 (issued Jun. 2, 1987) describes the reaction of a quaternary salt of an erythromycin A 9-oxime with a methylating reagent in the presence of a base such as an alkali metal hydride, hydroxide or alkoxide. U.S. Pat. No. 4,672,109 (issued Jun. 9, 1987) describes the reaction of an erythromycin A 9-oxime with a methylating reagent in the presence of a base such as an alkali metal hydride or hydroxide. European Application EP 260938 (published Mar. 23, 1988) describes 6-O-methylerythromycin derivatives prepared by the reaction of 2'-silylated erythromycin A 9-oximes with a methylating reagent in the presence of a base, such as an alkali metal hydride, hydroxide or alkoxide, that is said to prevent undesirable quaternary salt formation. U.S. Pat. No. 4,990,602 (issued Feb. 5, 1991) describes additional 6-O-methylerythromycin erythromycin A derivatives (more broadly substituted at the oxime position than those of EP 260938) prepared by the reaction of such 2'-silylated erythromycin 9-oxime derivatives with a methylating reagent in the presence of a base such as an alkali metal hydride, hydroxide or alkoxide, also with the stated intention of preventing undesirable quaternary salt formation. While the U.S. Pat. No. 4,990,602 and the EP 260938 application point out the desirability of preventing quaternary salt formation, there remains a need for alternative methods for improving yields.

The continued appearance of new patents directed to 6-O-methyl erythromycin compounds is an indication of the importance of and the continuing efforts towards preventing unwanted side-reactions and to increasing the yield of the desired antibiotic compounds (e.g., clarithromycin).

In general, the process for making clarithromycin can be thought of as a four-step procedure beginning with erythromycin A as the starting material:

- Step 1: optionally protect the 9-oxo group with an oxime;
- Step 2: protect the 2' and 4" hydroxyl groups;
- Step 3: methylate the 6-hydroxyl group;
- Step 4: deprotect at the 2', 4" and 9-positions.

We have now found that higher yields of 6-O-alkyl erythromycin derivatives may be obtained and by-product compounds reduced by means of a 6-O-alkylation procedure that utilizes a weak organic base in the presence of a strong base. This alkylation step corresponds to the general Step 3 referred to above.

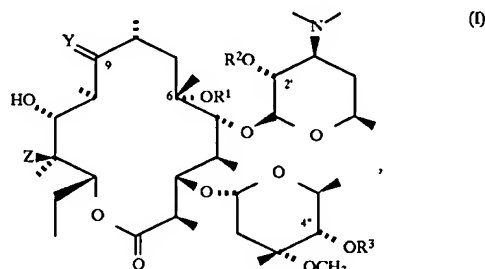
This procedure is especially useful when a mixture of hydroxy-protected erythromycin derivatives (and especially those protected with silyl compounds, eg., trimethylsilyl) is

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to be methylated. Such mixtures of hydroxy-protected erythromycin derivatives (i.e., mixtures of the 2'-mono-, 4"-mono, and 2',4"-bis-protected derivatives) may be produced during large scale preparations (i.e., in Step 2 referred to above) if the bis-protection is not fully achieved. The ability to perform the alkylation on a mixture of hydroxy-protected compounds is also a distinct advantage, as costly separation steps may be avoided.

SUMMARY OF THE INVENTION

The invention comprises a procedure for preparing 6-O-alkyl erythromycin compounds having the formula (I):



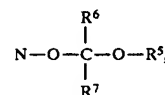
wherein:

R¹ is a loweralkyl group, as defined below;

R² and R³ are independently hydrogen or a hydroxy-protecting group, as defined below, except that R² and R³ may not both be hydrogen simultaneously;

Y is selected from the group consisting of:

- a) oxygen,
- b) an oxime having the formula N-O-R⁴, wherein R⁴ is selected from the group consisting of:
 - hydrogen,
 - a loweralkenyl group, as defined below,
 - a aryl(loweralkyl) group, as defined below, or
 - a substituted aryl(loweralkyl) group, as defined below; or
- c) an oxime having the formula



wherein

R⁵ is selected from the group consisting of:

- a loweralkyl group,
- a cycloalkyl group, as defined below,
- a phenyl group,
- an aryl(loweralkyl) group;
- or R⁵ and R⁶ or R⁵ and R⁷ and the atoms to which they are attached are taken together form a 5- to 7-membered ring containing one oxygen atom;

R⁶ is selected from the group consisting of:

- a loweralkyl group,
- a loweralkoxymethyl group, as defined below;
- or R⁶ and R⁵ and the atoms to which they are attached are taken together form a 5- to 7-membered ring containing one oxygen atom,
- or R⁶ and R⁷ and the atoms to which they are attached are taken together form a 5- to 7-membered cycloalkyl group; and

R⁷ is selected from the group consisting of:

- a hydrogen atom,
- a loweralkyl group,

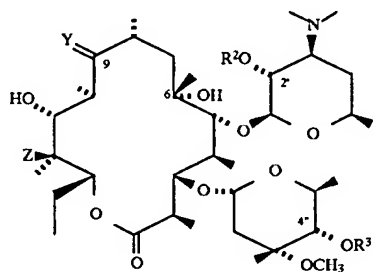
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a phenyl group,
 an aryl(loweralkyl) group;
 or R⁷ and R⁵ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered ring containing one oxygen atom;
 or R⁷ and R⁶ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered cycloalkyl group;

with the requirement that only one pair of substituents
 (R⁵ and R⁶), (R⁵ and R⁷) or (R⁶ and R⁷) may be taken
 together with the atoms to which they are attached to
 form a ring as defined above;

and

Z is hydrogen, hydroxy or protected-hydroxy; by reaction
 of a compound of having the formula

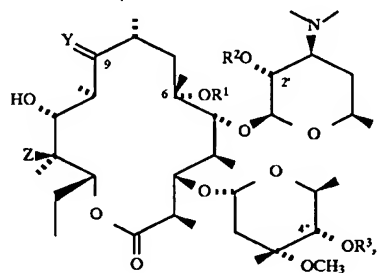


wherein R², R³, Y and Z are as defined above, with an
 alkylating reagent, as defined below, in the presence of a
 strong alkali metal base, as defined below, and also in the
 presence of a weak organic amine base, as defined below, in
 a stirred or agitated polar aprotic solvent, as defined below,
 or a mixture of such polar aprotic solvents maintained at a
 reaction temperature and for a period of time sufficient to
 effect alkylation.

The compounds produced by the process of the invention
 are subsequently deprotected at the 2' (R²) and 4" (R³)
 positions to give the commercially desired 6-O-alkyl anti-
 bacterial agents.

DETAILED DESCRIPTION OF THE INVENTION

In one embodiment (Embodiment A) of the invention is
 the procedure for preparing 6-O-alkyl erythromycin com-
 pounds having the formula (I):



wherein:

R¹ is a loweralkyl group;

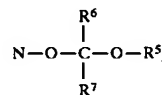
R² and R³ are independently hydrogen or a hydroxy-
 protecting group, which is benzyloxycarbonyl, acetyl, or a
 substituted silyl group of formula SiR⁸R⁹R¹⁰, wherein R⁸,
 R⁹ and R¹⁰ are the same or different and each is a hydrogen
 atom, a loweralkyl group, a phenyl-substituted alkyl group
 in which the alkyl moiety has 1 to 3 carbon atoms, a phenyl

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group, a cycloalkyl group having 5 to 7 carbon atoms, or a
 loweralkenyl group having 2 to 5 carbon atoms; with the
 requirements that at least one of R⁸, R⁹ and R¹⁰ is not a
 hydrogen atom and that R² and R³ may not both be hydrogen
 simultaneously;

Y is selected from the group consisting of:

- a) oxygen,
- b) an oxime having the formula N-O-R⁴, wherein
 R⁴ is selected from the group consisting of:
 hydrogen,
 a loweralkenyl group,
 an aryl(loweralkyl) group, or
 a substituted aryl(loweralkyl) group; or
- c) an oxime having the formula



wherein

R⁵ is selected from the group consisting of:

- a loweralkyl group,
- a cycloalkyl group,
- a phenyl group,
- an aryl(loweralkyl) group; or
- R⁵ and R⁶ or R⁵ and R⁷ and the atoms to which they
 are attached are taken together form a 5- to
 7-membered ring containing one oxygen atom;

R⁶ is selected from the group consisting of:

- a loweralkyl group,
- a loweralkoxymethyl group;
- or R⁶ and R⁵ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered ring containing one oxygen atom,
- or R⁶ and R⁷ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered cycloalkyl group; and

R⁷ is selected from the group consisting of:

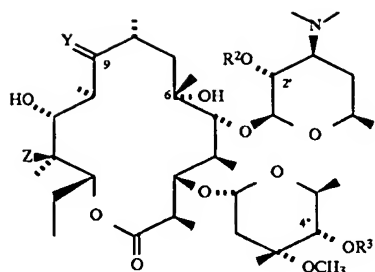
- a hydrogen atom,
- a lower alkyl group,
- a phenyl group,
- an aryl(loweralkyl) group;
- or R⁷ and R⁵ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered ring containing one oxygen atom;
- or R⁷ and R⁶ and the atoms to which they are
 attached are taken together form a 5- to
 7-membered cycloalkyl group;

with the requirement that only pair of substituents (R⁵
 and R⁶), (R⁵ and R⁷) or (R⁶ and R⁷) may be taken
 together with the atoms to which they are attached
 form to a ring as defined above;

and

Z is hydrogen, hydroxy or protected-hydroxy; by reaction
 of a compound having the formula:

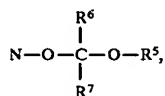
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wherein R^2 , R^3 , Y and Z are as defined above, with an alkylating reagent, typically comprising methyl bromide, ethyl bromide, *n*-propyl bromide, methyl iodide, ethyl iodide, *n*-propyl iodide, dimethyl sulfate, diethyl sulfate, di-*n*-propyl sulfate, methyl-*p*-toluenesulfonate, ethyl methanesulfonate, and *n*-propyl methanesulfonate, in the presence of a strong alkali metal base, preferably selected from the group consisting of an alkali metal hydride, alkali metal hydroxide or alkali metal alkoxide, and also in the presence of a weak organic amine base, preferably selected from the group consisting of trimethylamine, triethylamine, tripropylamine, pyridine, 2-methoxypyridine, 1-methylpyrrolidine, 1-methylpiperidine, and 1-ethylpiperidine, in a suitable stirred or agitated polar aprotic solvent, selected, for example, from the group consisting of *N,N*-dimethylformamide, dimethyl sulfoxide, *N*-methyl-2-pyrrolidone, hexamethylphosphoric triamide, tetrahydrofuran, 1,2-dimethoxyethane, acetonitrile or ethyl acetate, or a mixture of such polar aprotic solvents maintained at a reaction temperature and for a period of time sufficient to effect alkylation, preferably from -15°C . to room temperature for a period of one to 8 hours.

In another embodiment of the invention (Embodiment B) is that procedure of Embodiment A, wherein R^2 and R^3 independently are hydrogen or a substituted silyl group of formula $\text{SiR}^8\text{R}^9\text{R}^{10}$, wherein R^8 , R^9 and R^{10} are the same or different and each is a hydrogen atom, a loweralkyl group, a phenyl-substituted alkyl group in which the alkyl moiety has 1 to 3 carbon atoms, a phenyl group, a cycloalkyl group having 5 to 7 carbon atoms, or a loweralkenyl group having 2 to 5 carbon atoms; with the requirements that at least one of R^8 , R^9 and R^{10} is not a hydrogen atom and that R^2 and R^3 may not both be hydrogen simultaneously.

In another embodiment of the invention (Embodiment C) is that procedure of Embodiment A, wherein Y is an oxime having the formula



wherein

R^5 is selected from the group consisting of:

- a loweralkyl group,
- a cycloalkyl group, as defined below,
- a phenyl group,
- an aryl(loweralkyl) group;
- or R^5 and R^6 or R^5 and R^7 and the atoms to which they are attached are taken together form a 5- to 7-membered ring containing one oxygen atom;

R^6 is selected from the group consisting of:

- a loweralkyl group,
- a loweralkoxymethyl group, as defined below;

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or R^6 and R^5 and the atoms to which they are attached are taken together form a 5- to 7-membered ring containing one oxygen atom,

or R^6 and R^7 and the atoms to which they are attached are taken together form a 5- to 7-membered cycloalkyl group; and

R^7 is selected from the group consisting of:

- a hydrogen atom,
- a loweralkyl group,
- a phenyl group,
- an aryl(loweralkyl) group;
- or R^7 and R^5 and the atoms to which they are attached are taken together form a 5- to 7-membered ring containing one oxygen atom;
- or R^7 and R^6 and the atoms to which they are attached are taken together form a 5- to 7-membered cycloalkyl group;

with the requirement that only one pair of substituents (R^5 and R^6), (R^5 and R^7) or (R^6 and R^7) may be taken together with the atoms to which they are attached to form a ring as defined above;

In another embodiment of the invention (Embodiment D) is that procedure of Embodiment A, wherein Z is hydroxy.

In another embodiment of the invention (Embodiment E) is that procedure of Embodiment A, wherein the alkylating reagent is selected from the group consisting of methyl bromide, methyl iodide, dimethyl sulfate and methyl-*p*-toluenesulfonate.

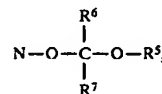
In another embodiment of the invention (Embodiment F) is that procedure of Embodiment A, wherein the reaction is maintained at a temperature from -5°C . to $+5^\circ\text{C}$.

In another embodiment of the invention (Embodiment G) is that procedure of Embodiment A, wherein the solvent is a mixture of solvents consisting of *N,N*-dimethylformamide, dimethyl sulfoxide, *N*-methyl-2-pyrrolidone, hexamethylphosphoric triamide, tetrahydrofuran, 1,2-dimethoxyethane, acetonitrile and ethyl acetate,

In another embodiment of the invention (Embodiment H) is that procedure of Embodiment A, wherein the strong alkali metal base is an alkali metal hydroxide

In another embodiment of the invention (Embodiment I) is that procedure of Embodiment A, wherein the weak organic amine base is selected from the group consisting of trimethylamine, triethylamine, tripropylamine, pyridine, 2-methoxypyridine, 1-methylpyrrolidine, 1-methylpiperidine and 1-ethylpiperidine.

In a preferred embodiment of the invention (Embodiment J) is that procedure of Embodiment A, wherein R^2 and R^3 are independently selected from hydrogen or a substituted silyl group of formula $\text{SiR}^8\text{R}^9\text{R}^{10}$, wherein R^8 , R^9 and R^{10} are the same or different and each is a hydrogen atom, a loweralkyl group, a phenyl-substituted alkyl group in which the alkyl moiety has 1 to 3 carbon atoms, a phenyl group, a cycloalkyl group having 5 to 7 carbon atoms, or a loweralkenyl group having 2 to 5 carbon atoms and with the requirements that at least one of R^8 , R^9 and R^{10} is not a hydrogen atom and that both R^2 and R^3 may not be hydrogen; Y is an oxime having the formula



wherein

- R^5 is selected from the group consisting of:
- a loweralkyl group,

a cycloalkyl group, as defined below,
 a phenyl group,
 an aryl(loweralkyl) group;
 or R⁵ and R⁶ or R⁵ and R⁷ and the atoms to which they
 are attached are taken together form a 5- to 7-membered ring containing one oxygen atom;

R⁶ is selected from the group consisting of:
 a loweralkyl group,
 a loweralkoxymethyl group, as defined below;
 or R⁶ and R⁵ and the atoms to which they are attached
 are taken together form a 5- to 7-membered ring
 containing one oxygen atom,
 or R⁶ and R⁷ and the atoms to which they are attached
 are taken together form a 5- to 7-membered
 cycloalkyl group; and

R⁷ is selected from the group consisting of:
 a hydrogen atom,
 a loweralkyl group,
 a phenyl group,
 an aryl(loweralkyl) group;
 or R⁷ and R⁵ and the atoms to which they are attached
 are taken together form a 5- to 7-membered ring
 containing one oxygen atom;
 or R⁷ and R⁶ and the atoms to which they are attached
 are taken together form a 5- to 7-membered
 cycloalkyl group;

with the requirement that only pair of substituents (R⁵ and
 R⁶), (R⁵ and R⁷) or (R⁶ and R⁷) may be taken together
 with the atoms to which they are attached to form a ring
 as defined above;

Z is hydroxy; the alkylating reagent is a methylating reagent
 consisting of methyl bromide, methyl iodide, dimethyl sul-
 fate or methyl-p-toluenesulfonate; the strong alkali metal
 base is an alkali metal hydroxide; wherein the weak organic
 amine base is selected from the group consisting of
 trimethylamine, triethylamine, tripropylamine, pyridine,
 2-methoxypyridine, 1-methylpyrrolidine,
 1-methylpiperidine, and 1-ethylpiperidine; the solvent is a
 mixture of solvents consisting of N,N-dimethylformamide,
 dimethyl sulfoxide, N-methyl-2-pyrrolidone, hexameth-
 ylphosphoric triamide, tetrahydrofuran, 1,2-
 dimethoxyethane, acetonitrile or ethyl acetate; and the reaction
 is maintained at a temperature from -5° C. to +5° C.

In a more preferred embodiment of the invention
 (Embodiment K) is that procedure of Embodiment A,
 wherein R² and R³ are independently hydrogen or a trim-
 ethylsilyl group but R² and R³ may not both be hydrogen
 simultaneously; Y is a isopropyl cyclohexyl ketal oxime
 group; Z is hydroxy; the alkylating reagent consists of
 methyl bromide, methyl iodide, dimethyl sulfate, or methyl-
 p-toluenesulfonate; the strong alkali metal base is potassium
 hydroxide; the weak organic amine base is triethylamine; the
 solvent is a mixture of THF and DMSO; and the reaction is
 maintained at a temperature from -5° C. to 0° C.

In another aspect of the invention are the novel interme-
 diate compounds, 4"-TMS-erythromycin A oxime IPCH
 ketal and 2'-TMS-erythromycin A oxime IPCH ketal.

DEFINITIONS

A number of defined terms are used herein to designate
 particular elements of the present invention. When so used,
 the following meanings are intended:

The term "alkyl" refers to saturated, straight- or branched-
 chain hydrocarbon radicals containing between one and ten
 carbon atoms including, but not limited to, methyl, ethyl,
 propyl, isopropyl, n-butyl, tert-butyl and neopentyl.

The term "alkylating reagent" refers to a reagent capable
 of placing an alkyl group onto a nucleophilic site, including,
 but not limited to, alkyl halides such as methyl bromide,
 ethyl bromide, n-propyl bromide, methyl iodide, ethyl
 iodide, n-propyl iodide; dialkyl sulfates such as dimethyl
 sulfate, diethyl sulfate, di-n-propyl sulfate; and alkyl or aryl
 sulfonates such as methyl-p-toluenesulfonate, ethyl
 methanesulfonate, n-propyl methanesulfonate, and the like.

The term "aryl(loweralkyl)" refers to a loweralkyl radical
 having appended thereto 1-3 aromatic hydrocarbon groups,
 as for example benzyl, diphenylbenzyl, trityl and phenyl-
 ethyl.

The term "aryloxy" refers to an aromatic hydrocarbon
 radical which is joined to the rest of the molecule via an
 ether linkage (i.e., through an oxygen atom), as for example
 phenoxy.

The term "cycloalkyl" refers to a saturated monocyclic
 hydrocarbon radical having from three to eight carbon atoms
 in the ring and optionally substituted with between one and
 three additional radicals selected from among loweralkyl,
 halo(loweralkyl), loweralkoxy, halogen. Examples of
 cycloalkyl radicals include, but are not limited to,
 cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl,
 cycloheptyl, 1-fluoro-cyclopropyl, 2-fluorocyclopropyl and
 2-aminocyclopropyl.

The term "hydroxy-protecting group" is well-known in
 the art and refers to substituents on functional hydroxy
 groups of compounds undergoing chemical transformation
 which prevent undesired reactions and degradations during
 a synthesis (see, for example, T. H. Greene and P. G. M.
 Wuts, *Protective Groups in Organic Synthesis*, 2nd edition,
 John Wiley & Sons, New York (1991)). Examples of
 hydroxy-protecting groups include, but are not limited to,
 benzyloxycarbonyl, acetyl, or a substituted silyl group of
 formula SiR⁸R⁹R¹⁰, wherein R⁸, R⁹ and R¹⁰ are the same or
 different and each is a hydrogen atom, a loweralkyl group,
 a phenyl-substituted alkyl group in which the alkyl moiety
 has 1 to 3 carbon atoms, a phenyl group, a cycloalkyl group
 having 5 to 7 carbon atoms, or a loweralkenyl group having
 2 to 5 carbon atoms and wherein at least one of R⁸, R⁹ and
 R¹⁰ is not a hydrogen atom; and the like

The term "loweralkenyl" refers to a straight- or branched-
 chain hydrocarbon radical containing between two and six
 carbon atoms and possessing at least one carbon-carbon
 double bond. Examples of loweralkenyl radicals include
 vinyl, allyl, 2- or 3-butenyl, 2,3- or 4-pentenyl, 2,3,4- or
 5-hexenyl and isomeric forms thereof.

The term "loweralkoxy" refers to a loweralkyl radical
 which is joined to the rest of the molecule via an ether
 linkage (i.e., through an oxygen atom). Examples of lower-
 alkoxy radicals include, but are not limited to, methoxy and
 ethyloxy.

The term "loweralkyl" refers to an alkyl radical contain-
 ing one to six carbon atoms including, but not limited to,
 methyl, ethyl, propyl, isopropyl, n-butyl, tert-butyl and
 neopentyl.

The term "protected hydroxy" refers to a hydroxy group
 protected with a hydroxy protecting group, as defined above.

The term "polar aprotic solvent" refers to polar organic
 solvents lacking an easily removed proton, including, but
 not limited to, N,N-dimethylformamide, dimethyl sulfoxide,
 N-methyl-2-pyrrolidone, hexamethylphosphoric triamide,
 tetrahydrofuran, 1,2-dimethoxyethane, acetonitrile or ethyl
 acetate, and the like.

The term "strong alkali metal base" refers to an alkali
 metal base having a weak conjugate acid, including, but not

limited to, sodium hydroxide, potassium hydroxide, sodium hydride, potassium hydride, potassium t-butoxide, and the like.

The term "substituted aryl(loweralkyl)" refers to an aryl (loweralkyl) residue as defined above having between one and three non-hydrogen ring substituents, each independently selected from among halogen, loweralkoxy, loweralkyl, hydroxy-substituted loweralkyl, and (loweralkyl)amino. Examples of substituted aryl (loweralkyl) radicals include 2-fluorophenylmethyl, 4-fluorophenylethyl and 2,4-difluorophenylpropyl.

The term "weak organic amine base" refers to an organic amine base having a strong conjugate acid, including, but not limited to trimethylamine, triethylamine, tripropylamine, pyridine, 2-methoxypyridine, 1-methylpyrrolidine, 1-methylpiperidine, and 1-ethylpiperidine, and the like.

ABBREVIATIONS

Certain abbreviations are used repeatedly in the specification which follows. These include: DMSO for dimethyl sulfoxide; HPLC for high performance liquid chromatography; IPCH ketal for isopropyl cyclohexyl ketal; TEA for triethylamine; THF for tetrahydrofuran; TMS for trimethylsilyl.

STARTING MATERIALS

2',4"-bisTMS-erythromycin A oxime IPCH ketal was prepared as described in Example 30 of U.S. Pat. No. 4,990,602.

Preparation of 4"-TMS-erythromycin A oxime IPCH ketal
4"-TMS-erythromycin A oxime IPCH ketal was prepared by treating 2',4"-bisTMS-erythromycin A oxime IPCH ketal with acetic acid in a mixture of THF, DMSO and isopropyl alcohol at room temperature for 2 hours and 20 minutes, then diluting the mixture with isopropyl acetate and quenching with excess 2N NaOH. The organic layer was separated and dried, and the solvent was removed under vacuum to afford the 4"-TMS-erythromycin A oxime IPCH ketal. ¹H NMR assignments for the desosamine portion of the molecule are: 1', 4.57; 2', 3.20; 3', 2.44; 4', 1.69 & 1.21; 5', 3.45; 6', 1.21; OTMS (9H), 0.12. The integral of the TMS signal (9H) indicates that a single TMS group is present in the molecule. An NOE in the ROESY spectrum between the TMS group at 0.12 ppm and H2' at 3.20 ppm indicates that the TMS group is at the 2' position.

2'-TMS-erythromycin A oxime IPCH ketal

2'-TMS-erythromycin A oxime IPCH ketal was prepared by treating 2',4"-bisTMS-erythromycin A oxime IPCH ketal with 0.5N NaOH and TEA in 1:1 THF:DMSO for 2.5 hours at room temperature. The reaction was quenched with heptane and 2N NaOH, and the layers were separated. The organic layer was washed with water and dried over MgSO₄, then the solvent was removed under vacuum with additional flushing of the heptane with nitrogen to afford the 2'-TMS-erythromycin A oxime IPCH ketal. The structure was confirmed by NMR. ¹H NMR assignments for the cladinose portion of the molecule are: 1", 4.90; 2", 2.36 & 1.50; 3"-methyl, 1.14; 4", 3.16; 5", 4.24; 6", 1.22; Omethyl, 3.29; OTMS (9H), 0.14. The integral of the TMS signal (9H) indicates that a single TMS group is present in the molecule. An NOE in the ROESY spectrum between the TMS group at 0.14 ppm and H4" at 3.16 ppm indicates that the TMS group is at the 4" position.

EXAMPLES

The following examples, which are provided for illustration and not limitation of the invention, will serve to further illustrate the process and the advantages of the invention.

Where mixtures of starting material are utilized, the starting material is dissolved in the appropriate solvent and analyzed by HPLC, thus providing an exact estimate of each individual compound. A similar HPLC analysis was performed on the mixtures of products, to provide an exact estimate of each product compound.

Example 1

Methylation of 2',4"-bisTMS-erythromycin A oxime IPCH ketal:

Reference methylation procedure with KOH base and no TEA

A solution of 2',4"-bisTMS-erythromycin A oxime IPCH ketal (4.0 mmol) in 1:1 THF:DMSO (50 mL) was prepared. The solution was cooled to 0°-5° C., and methyl iodide (2.34 g, 16.5 mmol) and KOH (0.47 g, 8.3 mmol) were added in that order. The reaction mixture was stirred for 60 minutes, the reaction was diluted by addition of 100 mL of heptane, and 20 mL of 2N NaOH were added to quench the reaction. The layers were separated, and the organic layer was washed with water. The heptane layer was dried over MgSO₄, and the solvent was removed under vacuum to afford 3.86 g of product containing 2.99 g of the 6-O-methyl-2',4"-bisTMS-erythromycin A oxime IPCH ketal (71% yield). The identity of the product was confirmed by HPLC analysis and comparison with the reference product (see U.S. Pat. No. 4,990,602). See Table 1 below for a summary of Examples 1, 2 and 3.

Example 2

Methylation of 2',4"-bisTMS-erythromycin A oxime IPCH ketal;

Methylation Procedure with KOH and Low Level of TEA

The procedure of Example 1 was followed, except TEA (1.0 g, 10 mmole) was added prior to the addition of the methyl iodide and KOH. A crude product (4.14 g) was obtained which contained 3.4 g of the 6-O-methyl products (81% yield). See Table 1 below for a summary of Examples 1, 2 and 3.

Example 3

Methylation of 2',4"-bisTMS-erythromycin A oxime IPCH ketal;

Methylation procedure with KOH and high level of TEA

The procedure of Example 1 was followed, except TEA (3.5 g, 34.6 mmole) was added prior to the addition of the methyl iodide and KOH. A crude product (3.84 g) was obtained which contained 3.5 g of the 6-O-methyl products (83% yield). See Table 1 below for a summary of Examples 1, 2 and 3.

TABLE 1

Summary of Examples 1, 2 and 3.

Ex. No.	Base	starting material (mmol)	6-O-methyl prod (g)	yield (%)
1	KOH	4.0	2.99	71
2	KOH + low TEA	4.0	3.4	81
3	KOH + high TEA	4.0	3.5	83

These data demonstrate that higher yields of product are obtained in the presence of TEA and that the yield is highest at the higher TEA level.

Example 4

Methylation of a mixture of 2',4"-bisTMS-erythromycin A oxime IPCH ketal and 4"-TMS-erythromycin A oxime IPCH ketal;

Reference methylation procedure with KOH base and no TEA

A solution of a mixture of 2',4"-bisTMS-erythromycin A oxime IPCH ketal and 4"-TMS-erythromycin A oxime IPCH ketal (3.07 and 1.0 mmol, respectively) in 1:1 THF:DMSO (50 mL) was prepared. The solution was cooled to 0°–5° C., and methyl bromide (0.85 g, 9.0 mmol) and KOH (0.47 g, 8.3 mmol) were added in that order. The reaction mixture was stirred for 30 minutes, then the reaction was diluted by addition of 100 mL of heptane, and 20 mL of 2N NaOH were added to quench the reaction. The layers were separated, and the organic layer was washed with water. The layers were separated, and a gummy by-product was collected. The heptane layer was dried over MgSO₄, and the solvent was removed under vacuum to afford 2.95 g of product identified as the 6-O-methyl-2',4"-bisTMS-erythromycin A oxime IPCH ketal (overall yield 69%). No methylated 4"-TMS product was obtained. The identity of the product was confirmed by comparison of its NMR spectrum with that of the reference product (see U.S. Pat. No. 4,990,602). The gummy by-product was dissolved in 25 mL of isopropyl acetate. The solution was dried and filtered, and the solvent removed under vacuum to give 0.91 g of a material identified as a quaternary salt by NMR spectroscopy. See Table 2 below for a summary of Examples 4, 5 and 6.

Example 5

Methylation of a mixture of 2',4"-bisTMS-erythromycin A oxime IPCH ketal and 4"-TMS-erythromycin A oxime IPCH ketal:

Methylation procedure with KOH and low level of TEA

The procedure of Example 4 was followed, except that the order of addition of reagents to the solution of starting materials was TEA (1.0 g, 10.0 mmol), methyl bromide, then KOH, to afford 3.93 g of a mixture of desired products, 6-O-methyl-2',4"-bisTMS-erythromycin A oxime IPCH ketal and 6-O-methyl-4"-TMS-erythromycin A oxime IPCH ketal (2.58 and 0.44 mmol, respectively; overall yield 74%). A modest amount of the quaternary by-product (0.41 g) was isolated. See Table 2 below for a summary of Examples 4, 5 and 6.

Example 6

Methylation of a mixture of 2',4"-bisTMS-erythromycin A oxime IPCH ketal and 4"-TMS-erythromycin A oxime IPCH ketal;

Methylation procedure with KOH and high level of TEA

The procedure of Example 4 was followed, except that the order of addition of reagents to the solution of starting materials was TEA (3.5 g, 34.6 mmol), methyl bromide, then KOH, to afford 3.87 g of a mixture of desired products, 6-O-methyl-2',4"-bisTMS-erythromycin A oxime IPCH ketal and 6-O-methyl-4"-TMS-erythromycin A oxime IPCH ketal (2.48 and 0.72 mmol, respectively; overall yield 79%). A trace amount of the quaternary by-product was obtained. See Table 2 below for a summary of Examples 4, 5 and 6.

TABLE 2

Summary of Example 4, 5 and 6.						
Ex. No.	Base	starting material (mmol)		6-O-methyl product (mmol)		combined yield %
		2',4"-bis-TMS	4"-mono-TMS	2',4"-bis-TMS	4"-mono-TMS	
4	KOH	3.07	1.0	2.81	0	69
5	KOH + low TEA	3.07	1.0	2.58	0.45	74

TABLE 2-continued

Summary of Example 4, 5 and 6.						
Ex. No.	Base	starting material (mmol)		6-O-methyl product (mmol)		combined yield %
		2',4"-bis-TMS	4"-mono-TMS	2',4"-bis-TMS	4"-mono-TMS	
6	KOH + high TEA	3.07	1.0	2.48	0.72	79

These data demonstrate that higher combined yields of product are obtained in the presence of TEA and that combined yields are highest at the higher TEA level.

Example 7

Methylation of mono-protected 4"-TMS-erythromycin A oxime IPCH ketal:

Methylation procedure with KOH only:

4"-TMS-erythromycin A oxime IPCH ketal (2.1 g, 2.2 mmol) was dissolved in 1:1 THF:DMSO (25 mL). The solution was cooled to 0°–5° C., and methyl bromide (1.5 mL, 27 mmol) and KOH (0.2 g, 3.0 mmol) were added in that order. The reaction mixture was stirred for 1 hour, the reaction was diluted by addition of 50 mL of heptane, and 10 mL of 2N NaOH were added to quench the reaction. The layers were separated, a gummy by-product was collected, and the organic layer was washed with water. The heptane layer was dried over MgSO₄, and the solvent was removed under vacuum. No product was observed. The gummy by-product was dissolved in 50 mL of isopropyl acetate. The solution was dried and filtered, and the solvent was removed under vacuum to give 1.5 g of a material identified as a quaternary salt by NMR spectroscopy. See Table 3 below for a summary of Examples 7 and 8.

Example 8

Methylation of mono-protected 4"-TMS-erythromycin A oxime IPCH ketal;

Methylation procedure with KOH and TEA:

The procedure of Example 7 was followed, except that the order of addition of reagents to the solution of starting material was TEA (3.5 g, 34.6 mmol), methyl bromide (0.5 mL, 9 mmol), then KOH (0.26 g, 3.9 mmol), to afford 1.32 g of the desired product, 6-O-methyl-4"-TMS-erythromycin A oxime IPCH ketal (68% yield), and 0.32 g of the quaternary by-product. See Table 3 below for a summary of Examples 7 and 8.

TABLE 3

Summary of Examples 7 and 8.				
Ex. No.	Base	starting material (mmol)	6-O-methyl prod (g)	yield (%)
7	KOH	2.2	0	0
8	KOH + high TEA	2.2	1.32	68

These data demonstrate no yield of 4"-mono-protected product is obtained without the presence of TEA.

Example 9

Methylation of mono-protected 2'-TMS-erythromycin A oxime IPCH ketal:

Methylation procedure with KOH only

2'-TMS-erythromycin A oxime IPCH ketal (2.1 g, 2.2 mmol) was dissolved in 1:1 THF:DMSO (25 mL). The